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Electrically tunable lens EL-3.1-10.8

The compact EL-3.1-10.8 lens is designed for OEM integration into optical systems for various applications. The working principle is based on Optotune's well-established shape-changing lens technology. The curvature of the lens is adjusted by applying an electrical current. Thereby, the focal length is tuned to a desired value within a few milliseconds. The lens architecture is "push & pull" which means that the lens curvature is deflected from concave to convex. With actuators based on proven voice-coil technology, the EL-3.1-10.8 tunable lens is ultra-compact in design and offers a reliable focusing solution for large focus ranges.

Lens specifications

Optical clear aperture	3.1	mm
Outer dimension of lens main body	Ø10.8	mm
Height	1.72	mm
Focal power range: (25°C, ±125 mA, all orientations)	-8 to +8 class 1: -8 to +10	dpt
Focal power range: (-20°C to +60°C, ±125 mA, all orientations)	-5.5 to +7.5 class 1: -5.5 to +9	dpt
Wavelength range (*Customizable)	420 to 950	nm
Transmittance with AR coating	95	%
Focal power @ 0 mA (25°C, typical)	-2 to +2	dpt
Orientation Sensitivity @0mA (dpt/g)	0.6	dpt
Wavefront error @ 0 dpt (Optical axis vertical / horizontal)	< 0.20 / < 0.20 class 1: < 0.07 / < 0.07	λ RMS @ 532 nm at 80% of clear aperture
Optical Axis Accuracy (max, -8dpt to 0dpt)	5	mrad
Optical Axis Accuracy (max, 0dpt to +5dpt)	5-12	mrad
Optical Axis Accuracy (max, +5dpt to +8dpt)	12	mrad
Optical Axis Repeatability	0.05	mrad
Lens type	plano-concave to plano-convex	
Refractive index / Abbe number	n_D = 1.29 / v = 100	
Response time (typ. at 25°C, 0 to ±50 mA step, +/-1% target)	1	ms
Settling time (typ. at 25°C, 0 to ±50 mA step, +/-1% target)	4 (with signal conditioning) 7 (rectangular step)	ms
Lifecycles (-100mA to + 100mA, sinusoidal, 200Hz)	> 1'000'000'000	
Weight	0.3	g

Electrical specifications

Nominal control current	-125 to 125	mA
Absolute max. control current	-150 to 150	mA
Motor coil resistance @ 25°C	8.5	Ω
Power consumption for 10 dpt range	20	mW
Power consumption for 16 dpt range	85	mW

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Environmental specifications

Operating temperature	-20 to 85	°C
Storage temperature	-40 to 85	°C

Overview of available standard products

Standard Product	Tuning Range (25°C, ±125 mA, all orientations)	Wavefront error	Wavelength range
EL-3.1-10.8-VIS-16D-OEM	-8 to 8 dpt	0.2 λ RMS	420 – 950 nm
EL-3.1-10.8-VIS-16D-FPC55	-8 to 8 dpt	0.2 λ RMS	420 – 950 nm
EL-3.1-10.8-VIS-16D-1-OEM	-8 to 10 dpt	0.07 λ RMS	420 – 950 nm
EL-3.1-10.8-VIS-16D-1-FPC55	-8 to 10 dpt	0.07 λ RMS	420 – 950 nm

Mechanical layout

The EL-3.1-10.8 comes with a PCB with embedded coils. The relevant mechanical drawings of the main body are depicted in Figure 1.

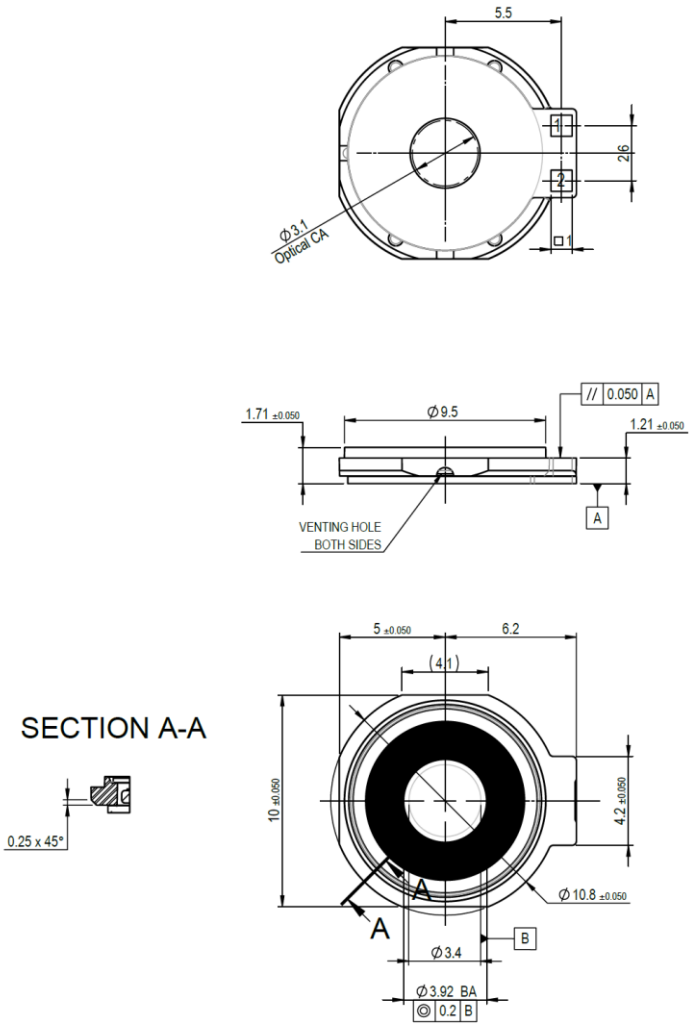

Figure 1: Mechanical drawing of the EL-3.1-10.8 (unit: mm).

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The lens is also available with a 55mm flex, as shown in Figure 2.

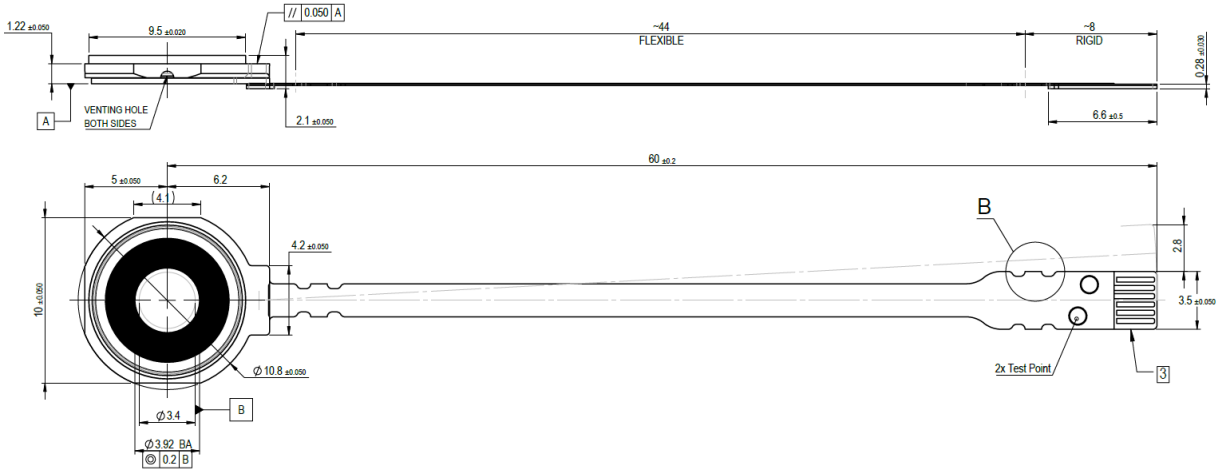

Figure 2: EL-3.1-10.8 with 55mm flex cable

Optical Layout

A simplified schematic of the optical layout is shown in Figure 3. For further details, including material optical properties, please refer to the Zemax file, available in the Optotune resource hub (https://www.optotune.com/resource-hub/).

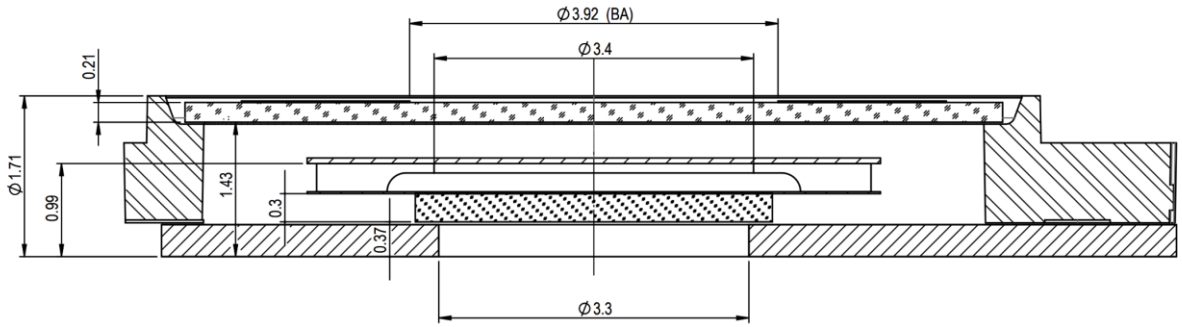

Figure 3: Optical layout of the EL-3.1-10.8.

Mechanical Integration

The lens can be mounted using the flange on the housing. The housing itself is made from liquid crystal polymer. There are D-cuts on three sides of the lens for controlling orientation. No pressure should be applied to the cover glass on the PCB side. Pressure on the PCB itself risks degradation of the optical quality. For further information please refer to the handling instructions available in the Optotune resource hub (https://www.optotune.com/resource-hub/).

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Electrical Connection

To provide flexibility in the system integration, the EL-3.1-10.8 can be provided with an extension flex cable as shown in Figure 4: EL-3.1-10.8 with flex cable.. The end of the cable features a stiffened connection head with 6 pins suitable for Amphenol SFV12R-2STE1HLF 1-sided (safe), Molex 503480-0600 2-sided (careful with orientation) or equivalent connectors.

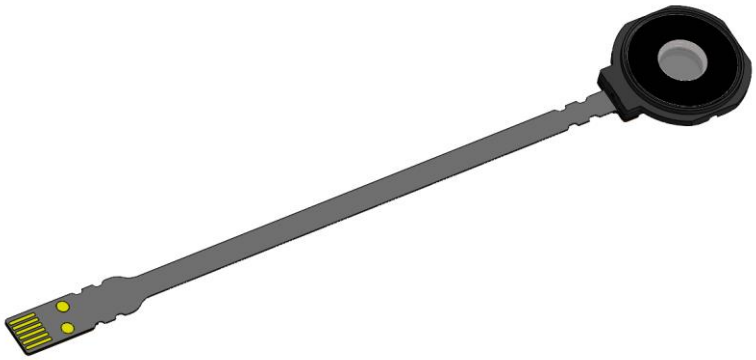
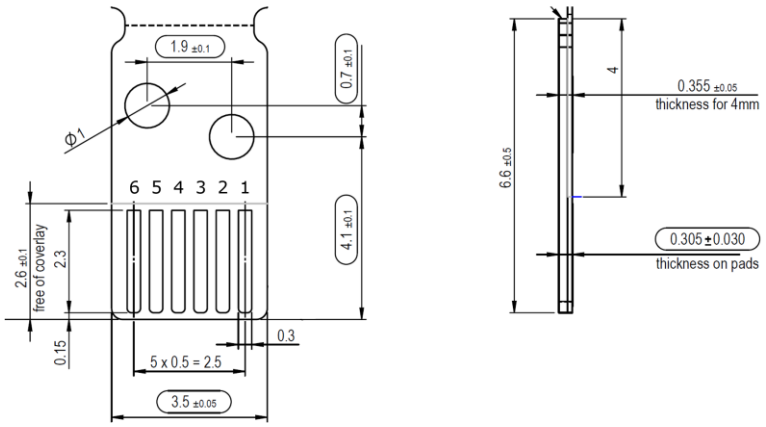


Figure 4: EL-3.1-10.8 with flex cable.

The pinout of the extension flex for EL-3.1-10.8 is shown in Figure 5.



Position	Function
1	NC
2	Control current -
3	Control current +
4	NC
5	NC
6	NC

Figure 5: Pin assignment of the extension flex

There are two pads exposed on the PCB that can be used to electrically contact the lens. The contact pads are copper with a Nickel/Palladium/Gold 1.5/0.01/0.005µm surface finish. See also handling note.

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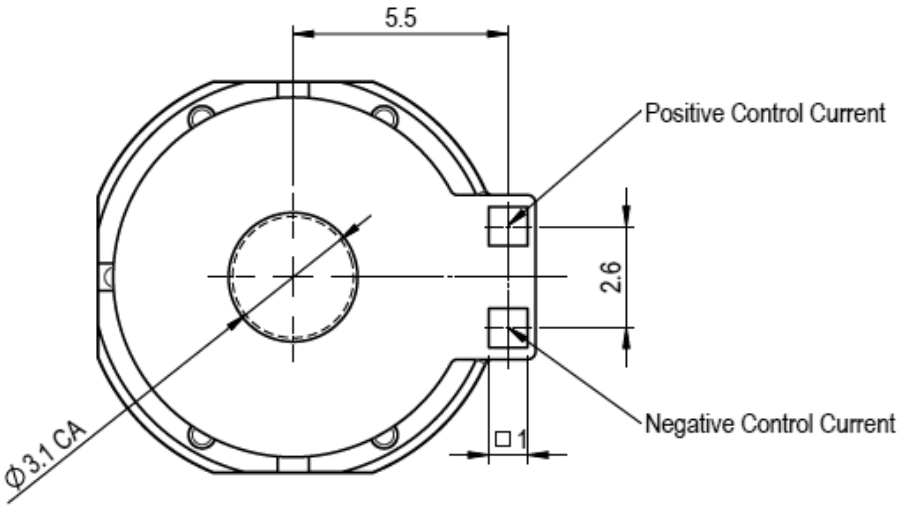

Figure 6: Contact pad layout of the EL-3.1-10.8

Liquid lens working principle

The working principle of the EL-3.1-10.8 is based on Optotune's well-established technology of shape-changing polymer lenses. The core that forms the lens contains an optical fluid, which is sealed off with an elastic polymer membrane as shown in Figure 7. An electromagnetic actuator is used to exert pressure on the container and therefore changes the curvature of the lens. By changing the electrical current flowing through the coil of the actuator, the focal power of the lens is controlled.

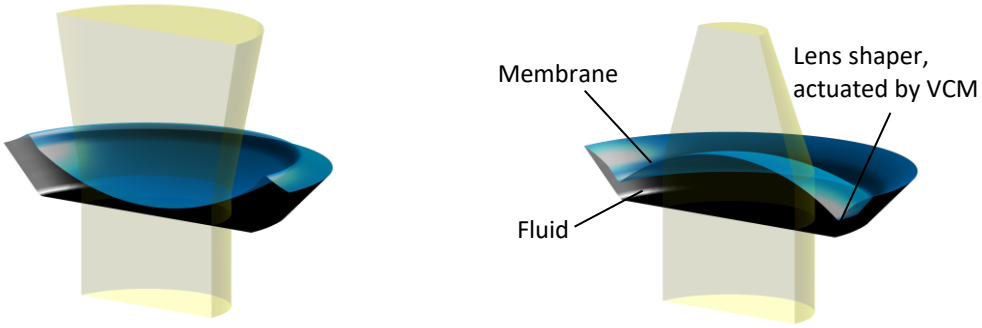

Figure 7: Working principle of the EL-3.1-10.8

Focal power versus current

The focal power of the EL-3.1-10.8 increases with positive and decreases with negative current as shown in Figure 8. When driving the lens up to absolute maximum control current, the tuning range increases further but increased heat generation must be considered. The focal power of the EL-3.1-10.8 lens is affected by acceleration and a change from 1g to -1g results in approximately 1.2dpt change in focal power.

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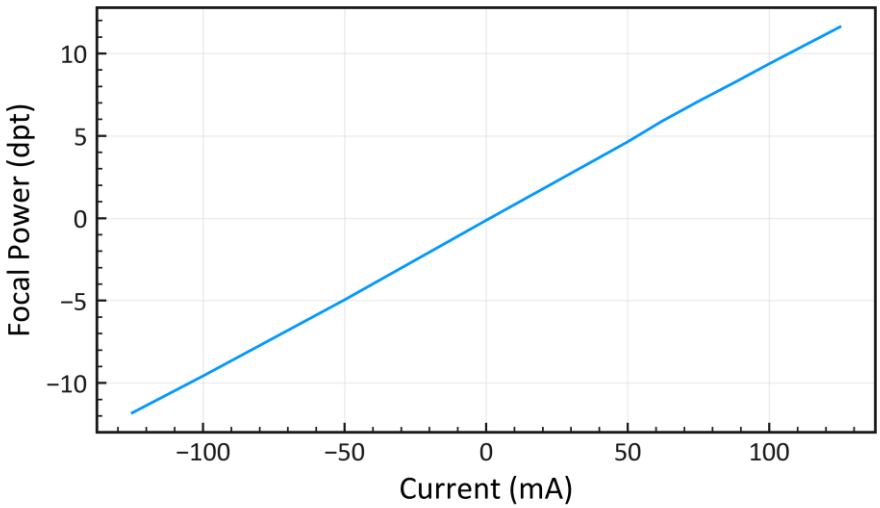

Figure 8: Typical data showing the relation between focal power (in diopters) and electrical current. Here we show the curve for vertical optical axis, with the membrane facing down.

Transmission

Both the optical fluid and the membrane material are highly transparent in the range of 400 to 2500 nm. The standard membrane exhibits a Fresnel reflection of 3-4% over that range. Cover glasses can be coated as desired. Figure 9 shows the transmission spectrum of the standard EL-3.1-10.8 using broadband coated cover glasses.

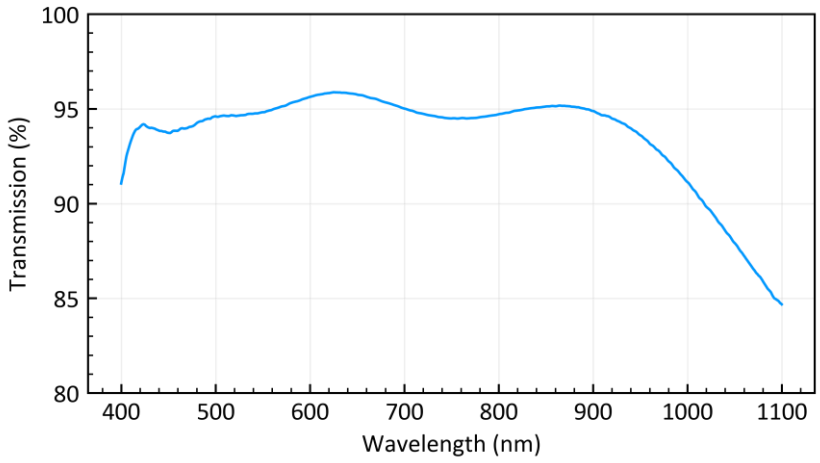

Figure 9: Transmission spectrum of standard EL-3.1-10.8.

Wavefront quality

Figure 10 shows the wavefront error as a function of focal power from different modules. The wavefront quality varies from lens to lens and can be specified differently upon request. A typical wavefront performance is in the range of 0.05λ RMS as depicted in Figure 10. Optotune's focus tunable lenses are typically subject to gravity-induced coma aberrations when used in the horizontal optical axis. In the case of the EL-3.1-10.8 this is approximately 0.015 λ.

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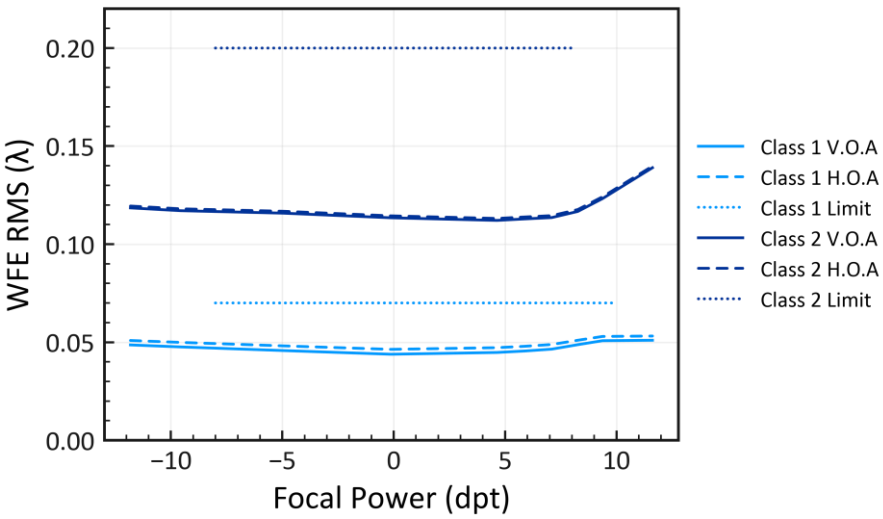

Figure 10: Typical wavefront error of a class 1 and class 2 EL-3.1-10.8 vs focal power with vertical optical axis (V.O.A) and horizontal optical axis (H.O.A). We can also see the specified maximum wavefront error of 0.2 λ and 0.07 λ for class 2 and class 1, respectively. These measurements are performance at 525nm, and the wavefront error is evaluated over 80% of the clear aperture).

At higher positive focal powers, the EL-3.1-10.8 can exhibit prism on the order of 1dpt, or 10mrad. Typical performance is shown in Figure 11. This prism magnitude can vary lens to lens, but for a given lens is very repeatable to within 5mdpt or 0.05mrad. For applications where line of sight stability is critical it is recommended to operate the lens at low or negative focal powers.

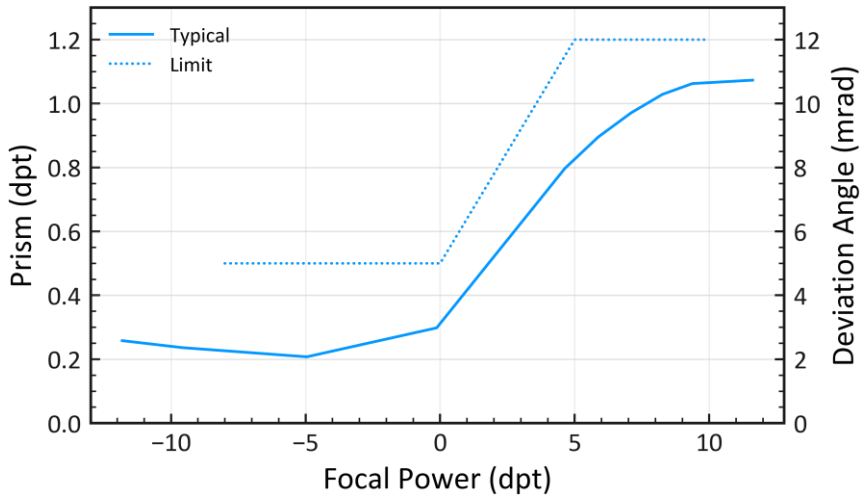

Figure 11: Typical prism of the EL-3.1-10.8.

Response time

The EL-3.1-10.8 exhibits a very fast response time of 1 ms and a settling time of 7 ms based on a rectangular step. Optotune controllers can provide appropriate signal conditioning, which is able to half the settling time, as shown in Figure 12. For more information, please contact sales@optotune.com.

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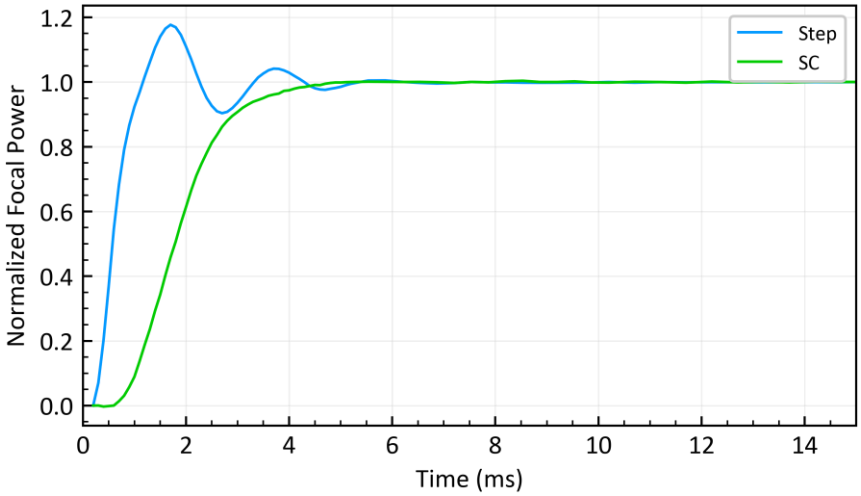

Figure 12: The settling time can be improved with signal conditioning (SC). Measurements taken at 30°C.

The frequency response over a broad range is presented in Figure 13, showing a resonance peak at around 350 Hz. Due to the excitation of higher order modes, and the associated increase in wavefront error, the lens can generally not be used for imaging applications around the resonant frequency. When applying a current step, it is recommended to damp frequencies above 200 Hz range by using a low pass filter. This avoids excitation oscillations close to the resonant frequency.

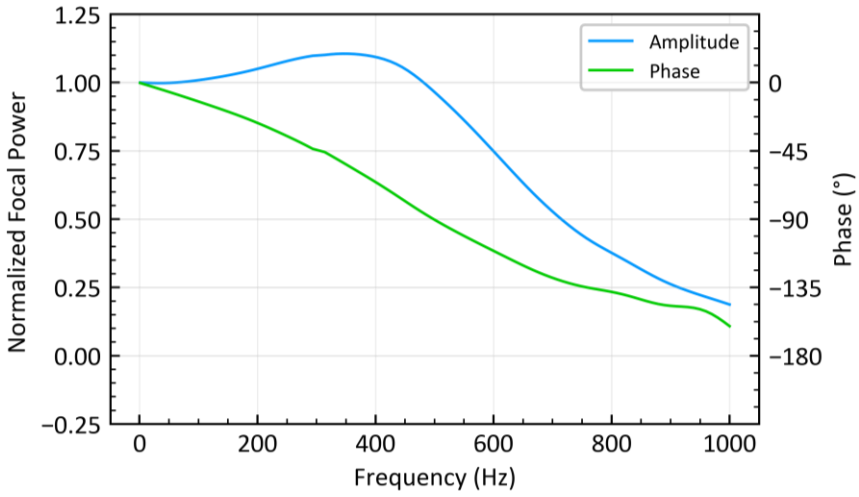

Figure 13: Typical frequency response of the EL-3.1-10.8. The driving amplitude is -25 to 25 mA

Temperature effects

Residual temperature effects influence the long-term drift of focal power stated in the specification table. These temperature effects are quantified by the temperature sensitivity S (dpt/°C), giving the change in focal power per

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degree Celsius. As shown in Figure 14, there is an almost linear dependence of S with focal power. Generally, temperature effects can be minimized when the EL-3.1-10.8 is thermally connected to a heat sink (large mass with high thermal conductivity).

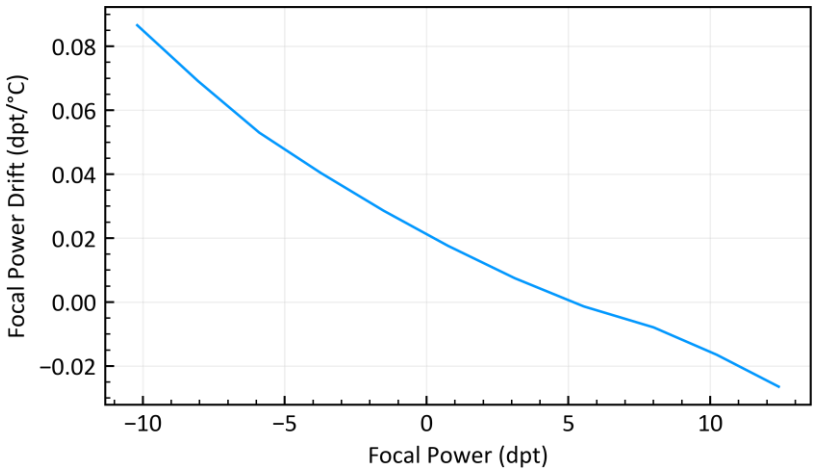

Figure 14: Temperature sensitivity as a function of focal power.

As the thermal drift is positive for the most negative focal powers, and negative for the most positive focal power, a reduction in tuning range is observed for elevated temperatures Figure 15: Typical tuning range as a function of operating temperature. Figure 15 shows the achievable tuning range over the entire operating temperature range.

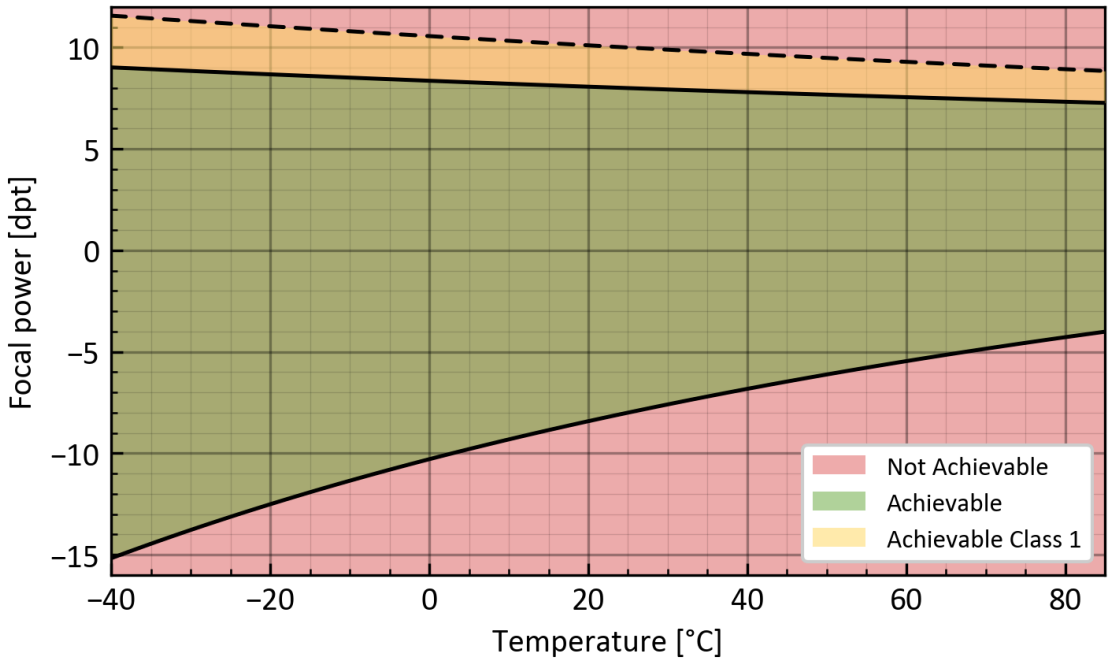

Figure 15: Typical tuning range as a function of operating temperature.

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Autofluorescence, birefringence & polarization effects

The EL-3.1-10.8 is neither auto-fluorescent, birefringent or in any other way polarization dependent.

Lifetime and reliability

The EL-3.1-10.8 is tested to the environmental and accelerated aging tests as outlined in Table 1. When applicable we have aligned our tests with those defined by ISO 9022: Optics and photonics – Environmental test methods.

Test	ISO
Mechanical cycling 1 billion full range cycles (-100mA to +100mA, sinusoidal, 200Hz)	-
Mechanical Shock 500g 1ms, 3 shocks along each axis	9022-30-08-1
Sinusoidal Vibration 10-500 Hz, 100 m/s², swept sine, 24 h per axis	EN 60068-2-6
High Temperature Storage 85±2 °C, rel. hum. <40%, 6h	9022-11-06-1
Low Temperature Storage -40±2 °C, 16h	9022-10-08-1
Solar Radiation 55°C ± 2°C, 1120 W/m2, 10 days	9022-9-04-1
Damp Heat 55±2 °C, rel. hum. 90% to 95%, 16h	9022-12-07-1
Temperature Shock -40 to 55 °C, 2.5h/cycle, <20s transition time, 5 cycles	9022-15-03-1

Table 1: Reliability and lifetime testing of the EL-3.1-10.8

Safety and compliance

The product fulfills the RoHS and REACH compliance standards. The customer is solely responsible for complying with all relevant safety regulations for integration and operation.

For more information on optical, mechanical, and electrical parameters, please contact sales@optotune.com.

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